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# Passive Water Distillation: Water Quality Analysis

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# Engaged Learning Final Report

PASSIVE WATER DISTILLATION: WATER QUALITY ANALYSIS

ELLE HOLBROOK





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## **1.0 Project Overview**

### **1.1 Introduction**

The Passive Water Distillation Project was created to ultimately improve the quality of life in areas of the world most affected by water stress, and assist in breaking through the laborious poverty cycle. The final goal was to design a sustainable, scalable, and replicable system that can supplement the drinking water supply of refugee camps and communities in developing nations. In partnership with Taylor Henry, this project consists of the design and construction of a unit which treats dirty or contaminated water and produces an effluent that is safe for human consumption. Installing these units in rural communities will enable them to focus on building a better infrastructure instead of spending the majority of their precious time and resources obtaining potable water for drinking and sanitation.

The Passive Water Distillation Project also includes a water sampling instruction component which was designed to help guide individuals correctly sample their drinking water using a simple, pictorial procedure which was specifically developed for Engaged Learning. With the use of the guide, communities will be able to accurately collect water samples that can then be analyzed on-site or sent to a laboratory for analysis. The purpose of this analysis is to check the current drinking water quality and find out what the specific drinking water needs are.

Henry's focus was on the quantitative aspects of designing and structuring the product, while I was focusing on the qualitative portions of the technology. My role in the project involved developing methods for monitoring and controlling necessary water quality parameters to ensure the drinking water is clean and safe for consumption.

### **1.2 Purpose**

Water use has been growing at more than twice the population increase in the last century. This effect is even more pronounced in developing countries. Originally, Honduras was the selected location to implement project, and was chosen because it is classified among the areas experiencing the most severe, physical water scarcity. Due to undergraduate travel restrictions, the plan to go to Honduras and build the Passive Water Distillation unit was not possible during the time frame of the project. However, implementation of the Passive Water Distillation unit in Honduras would work to satisfy basic human needs while preserving or restoring ecosystems and their functions. Honduras was an excellent candidate for testing and implementing the Passive Water Distillation system because it is an equatorial region, and the majority of places across the globe experiencing high levels of water stress share a similar climate model, as well as similar defining economic characteristics.

### **1.3 Basis of Design**

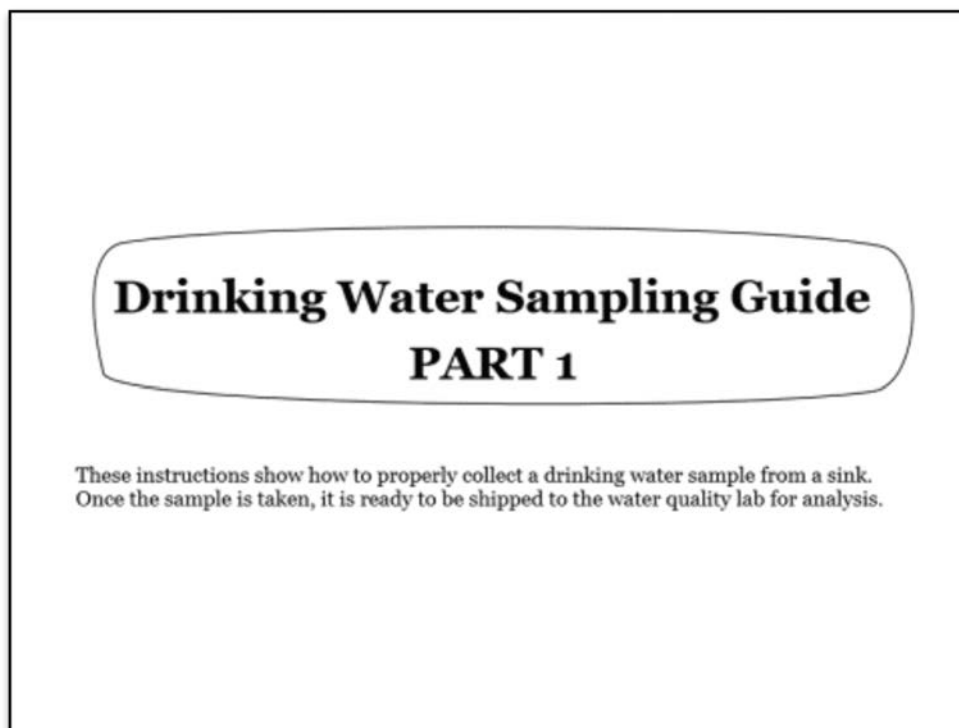
The Passive Water Distillation system operates free of external energy requirements as it utilizes solar energy exclusively. The treatment method used in the system is solar distillation. By selecting this technology, the system is capable of successfully cleaning water at different levels of contamination, from wastewater to rainfall. This is because solar distillation is an evaporative process that is able to extract pure H<sub>2</sub>O and leave behind the other constituents present in the influent water.

## 2.0 Field Sampling Instruction Kit

Instruction guide cards were developed with the intension to demonstrate the proper collection of a water sample in a manner that is simple to follow. The following images shown are meant to be published in the form of 8.5 x 11 inch cards. The hope was to train people on the site to sample their water and then ship the samples to me for laboratory analysis.

At the site, water is collected from the source (tap) into a 500 mL polypropylene Nalgene bottle rinsed three times with source water. Sample water is immediately transferred into a 10ml polypropylene syringe fitted with a 0.45 PTFE filter and a raw unfiltered sample is collected in a 15ml polypropylene centrifuge tube. Six aliquots are filtered into 1.5 mL polypropylene microcentrifuge tubes. Two aliquots are acidified with 33% HNO<sub>3</sub> to ~pH 2. The other four aliquots are unamended. Simultaneously, the 500 mL of sample water is analyzed for temperature, pH, dissolved oxygen (DO), conductivity, and oxidation reduction potential (ORP) using a YSI 556 MPS meter and probe (YSI Incorporated, Yellow Springs, OH).

### 2.1 Drinking Water Sampling Guide: Part 1



## Step 1

### Prepare for sample collection

---

**Materials:**

- Sample bottle
- Vinyl gloves
- Marking Pen

1. Wash hands
2. Remove aerators or other obstructions from faucet
3. Put on gloves
4. Turn on the sink and run water for 3-4 minutes
5. Remove cap from the sample bottle

NOTE: Do not touch the rim of the bottle or inside of the cap

## Step 2

### Rinsing sample bottle with drinking water

---



Begin filling sample bottle



Allow sample bottle to fill to up to rim



Slowly pour all of the water out of the bottle

### Repeat rinsing sample bottle

---



## Step 3

### Collect drinking water sample

---



Make sure the sample bottle is completely empty



Fill the sample bottle 80-90% full



## Step 4

Storing sample until shipping



1. Tightly screw the cap onto the sample bottle
2. Write the date on the bottle
3. Put the water sample in refrigerator
4. Ship the water sample as soon as possible

## 2.2 Drinking Water Sampling Guide: Part 2

This set of cards is meant to show field samplers how to acidify water samples so that they can be preserved for analysis in a water quality laboratory.

## Drinking Water Sampling Guide PART 2

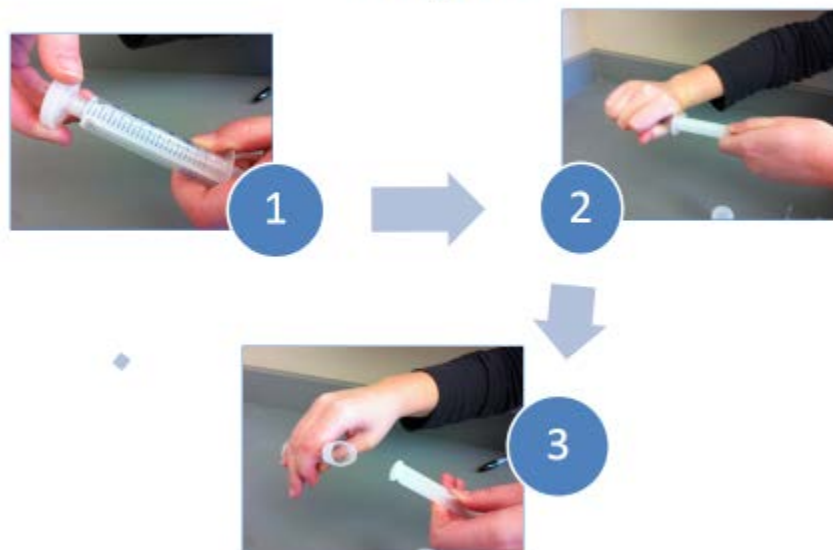




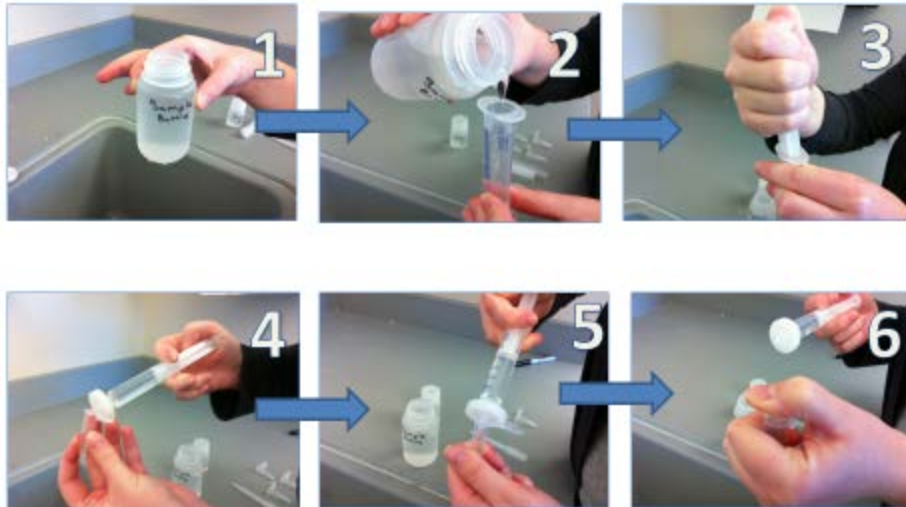
## Rinse, 3x



## Prepare



## Filter



## Finished Samples



### 2.3 Detection of Coliform Bacteria

Safe drinking water should contain a minimal amount of bacteria. It is important to test water for microbiological content before consumption. Standard methods for detecting coliform content use E.



coli as an indicator of bacteria present. The concentration of E. coli present in a water sample will help to determine if the water is safe to drink. This test must be done onsite since the bacteria are live organisms and cannot be accurately detected if the water is not fresh from the source. Since the site is not equipped to culture the water sample and growing the bacteria is a time consuming process, the presence of total coliforms will be determined by using a media color change test. This approach is known as a defined substrate technology. Colilert makes a commercial DST test for coliform detection, using a powder reagent that causes the water to change color based on the amount of bacteria present. This test is approved by the U.S. Environmental Protection Agency for drinking water analysis.

Instructions:

1. Collect the sample using the Drinking Water Sampling Guide.
2. Carefully pour sample water into tube containing the Colilert powdered media.
3. Tightly cap the tube.
4. Mix well by shaking and inverting the tube to dissolve the powder.
5. To achieve an incubation temperature, place the tube in your pant pocket for approximately 24 hours.
6. After 24 hour period, take tube out of pocket and observe any color change by comparing sample color to Colilert comparator and using the chart below.

Appearance	Result
Less yellow than the comparator	Negative for total coliforms
Yellow equal to or greater than the comparator	Positive for total coliforms

7. Record results on data sheet.

### 3.0 Analytical Methods

Laboratory techniques are described for the quality analysis of drinking water samples taken at the site in Honduras. The following techniques were used for preliminary data collection: Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), and Ion Chromatography (IC). These techniques were to be applied to additional samples collected in the field.

#### 3.1 Inductively Coupled Plasma – Mass Spectrometry (ICP-MS)

Inductively coupled plasma-mass spectrometry (ICP-MS) is used to determine dissolved metals in solution. Analyses are conducted on a Thermo XSeries 2 ICP-MS (Thermo Fisher Scientific, Waltham, MA) in collision cell mode with kinetic energy dispersion. Prior to analysis, an aliquot of the filtered acidified sample is diluted to both 50:1 (light dilution), and 1000:1 (heavy dilution) to accommodate the range of analytes. In general, major analytes are Ca, Mg, K, Na, and occasionally Fe. All others are typically in the trace analyte range, which included Li, Be, Al, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Se, Rb, Sr, Mo, Ag, Cd, Cs, Ba, Hg, Tl, Pb, Th, and U.

Calibration standards range from 0.05 ppb to 500 ppb and are prepared from a multi-element standard that includes all previously listed elements except for Hg, Mo, Th. Mo and Th are added to the multi-element standard from single analyte standards. Mercury is analyzed as a separate calibration curve at the end of each analysis to prevent element carryover. A 5% HNO<sub>3</sub> blank is also analyzed every 10 samples. Ultrapure 18 MΩ water (Barnstead Nanopure, Fisher Scientific, Pittsburgh, PA) and concentrated, trace metal grade HNO<sub>3</sub> (Fisher Scientific, Pittsburgh, PA) are used to prepare a 5% HNO<sub>3</sub> solution for making dilutions, calibration standards, blanks, and quality control samples.

**Figure 3-1: ICP Instrument at SMU**



## 3.2 Ion Chromatography (IC)

Anions are detected in the field samples using ion chromatography (IC) with a ICS-1100 (Dionex, Bannockburn, IL). Two separate analytical chromatography separation columns are used for analysis: the Dionex® IonPac® anion selective (AS)-18 (AS18) is used for nitrite and nitrate analysis, while the Dionex® IonPac® AS20 column is used for fluoride, iodide, and chloride analysis. Both columns are 4 x 250 mm. The use of two separate columns requires two separate analytical instrument runs for each sample. These cannot be performed simultaneously. Therefore, two instrumental samples are prepared for each sample collected in the field for IC analysis.

For each of the two IC runs, one filtered, unacidified field sample is filtered once more into a 5 mL IC vial using a syringe and 0.45 μm PTFE filter. The sample is massed and diluted to a volume of 5 mL. This is done twice for each sample—once for the AS18 column IC run and one for the AS20 column IC run.

Combined standards of the analytes for the column in use are prepared and also placed in the 5 mL IC vials. The eluent (mobile phase) for the AS18 column is 23 mM NaOH; the eluent for the AS20 column is 35 mM NaOH. These are prepared for each sample run in 2-L batches. Each column is run with

automatic eluent recycling with conductivity suppression. The suppression is performed at 60 mA for the AS18 columns and 90 mA for the AS20 column prior to conductivity detection. The flow rate is 1 mL/min with a total sample injection of 750  $\mu$ L for each injection. Sample blanks are run periodically to ensure instrument performance.

Each sample is analyzed for 18 min on the AS18 columns and 14 min on the AS20 column. The specific retention times are determined using the prepared standards. The area of each analyte peak is related to its concentration to create the calibration curve which is, in turn, used to calculate the unknown concentrations of the respective analyte in the samples.

**Figure 3-2: Prepping Samples from Passive Water Distillation System**



## 4.0 Laboratory Results

The ICP method previously described was used to determine the elements present in a water sample that was sent from the proposed site in Honduras. The purpose of analyzing this sample was to assess current water quality needs at the site. The IC method that was previously described was implemented for determination of phosphate concentration in the influent and effluent of the Passive Water Distillation unit on SMU's campus. The purpose of analyzing these samples was to test the removal efficiency of the Passive Water Distillation system.



## 4.1 Preliminary Data from Honduras

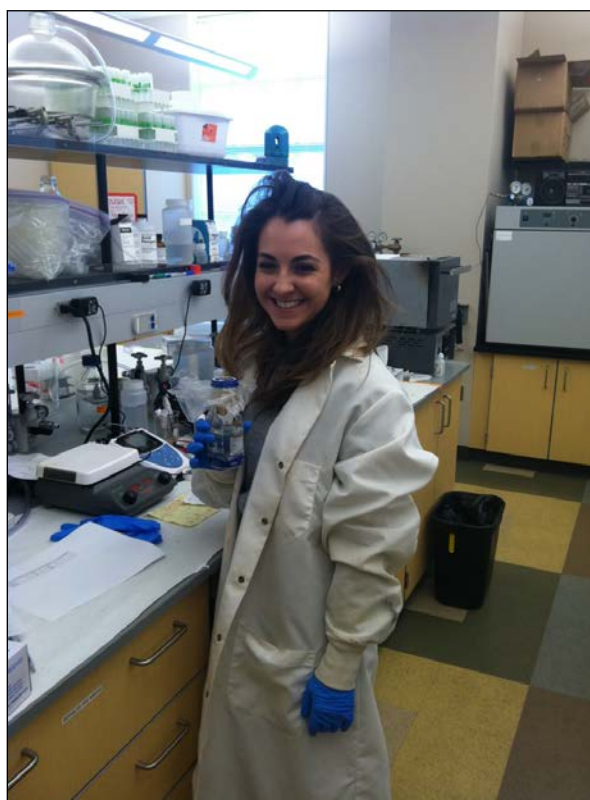
A sample was sent from the site in Honduras and analyzed in the Water Quality Lab at Southern Methodist University. The procedure that was used in the collection of this sample is unknown, and the bottle containing the sample was a beverage bottle, see Figure 4-1. The results from the ICP instrument shown in Table 4-1 are corrected sample concentrations in ppb (parts per billion) measured at a dilution factor of 50.

Usually, when checking basic water quality the elements the focus is on the concentrations of calcium (Ca), magnesium (Mg), potassium (K), and occasionally iron (Fe). Other constituents included in analysis are the following: lithium (Li), beryllium (Be), aluminum (Al), vanadium (V), chromium (Cr), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), gallium (Ga), arsenic (As), selenium (Se), rubidium (Rb), strontium (Sr), molybdenum (Mo), silver (Ag), cadmium (Cd), cesium (Cs), barium (Ba), mercury (Hg), thallium (Tl), lead (Pb), thorium (Th), and uranium (U). Most of these elements are typically found at very low concentrations so they are assumed to be not a significant source of contamination. For example, the presence of arsenic (As) at 2.4 ppb (parts per billion) would be considered a zero value because the concentration is so low. However, it is still important to look at the concentrations of all possible constituents in order to accurately quantify the drinking water quality.

**Figure 4-1: Sample from Honduras**



**Figure 4-2: Prepping Sample for Analysis**



**Table 4-2: Concentrations (ppb) of Constituents Present**

Li	Be	Na	Mg	Al	P	K
59.6	0.2	107121.6	33278.2	140.2	181.4	20215.2
Ca	V	Cr	Mn	Fe	Co	Ni
19191.1	2.5	12.6	428.3	217.3	2.4	70.8
Cu	Zn	Ga	As	Se	Kr	Rb
582.2	28094.5	584.4	2.4	29.0	514.0	31.7
Sr	Ag	Cd	Cs	Ba	Tl	Pb 206
373.7	1.6	10.3	0.1	3352.7	-0.6	4.0
Pb 207	Pb 208	U				
3.9	4.1	1.2				

## 4.2 Influent and Effluent Data

To demonstrate and measure the water purification capabilities of the Passive Water Distillation unit, water contaminated with a high level sodium phosphate was put into the system (Figure 4-3). A sample of the water put into the system (Figure 4-5 and 4-6) was collected and analyzed on the IC instrument to



be an initial value for comparison and is labeled as Influent in Table 4-2. The treated water that flows out of the system (Figure 4-6) was also collected and analyzed on the IC instrument as the final concentration and is labeled as Effluent 1 and Effluent 2 in Table 4-2. The IC instrument ran each of the three samples in triplicate as shown on Table 4-2, and a calibration curve for phosphorus was developed on the same day the samples were run, see Figure 4-7.

The comparison of these concentration values shows that the Passive Water Distillation system is capable of adequate removal of contaminants. The effluent concentration flowing into the collection contained significantly lower amounts phosphorus at an average of 0.03 ppm or 30 ppb in comparison to the influent water that was contaminated with phosphorus at a level of approximately 7 ppm or 700 ppb. The dramatic decrease in concentration demonstrates that the system has verifiable and efficient removal capabilities, effectively cleaning water and making it safe to drink.

**Figure 4-3: Adding Sodium Phosphorus to Water**



**Figure 4-4: Contaminated Influent**



**Figure 4-5: Influent Dispenser**



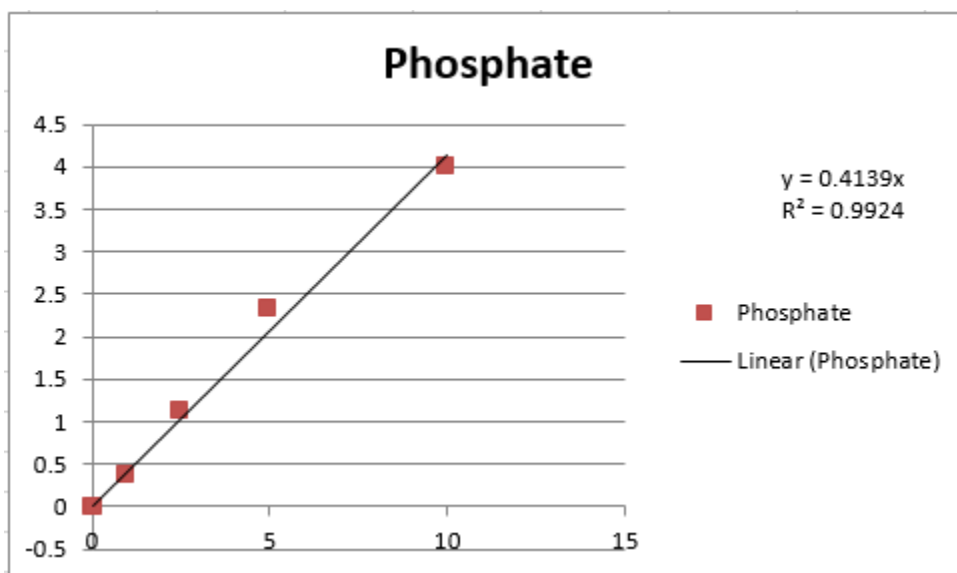
**Figure 4-6: Effluent Collection Bucket**



**Table 4-3: Phosphate Concentration (ppm)**

Sample	Area	Corrected Area	Avg. Corr. Area	Concentration
Blank	0.02			ppm
Effluent 1	0.07	0.04	0.01	
	0.01	-0.01		0.02
	0.01	-0.01		
Blank	0.01			
Effluent 2	0.07	0.06	0.02	0.04
	0.01	0.00		
	0.00	-0.01		
Blank	0.02			
Influent	2.41	2.39	2.85	6.88
	3.07	3.05		
	3.12	3.10		

Figure 4-7: Calibration Curve



### 4.3 Discussion

When taking a closer look that the concentrations of constituents present in the sample from Honduras, several observations and inferences can be made. Sodium (Na), magnesium (Mg), and manganese (Mn) are all present at normal levels compared with recommendations made by the World Health organization as well as the US Environmental Protection Agency. Potassium (K) and calcium (Ca) are present at a reasonable level compared with recommended standards. Aluminum (Al) and cadmium (Cd) are slightly higher than usual, but it do not exceed standards enough to be considered threatening. All other concentrations are classified as normal except for the zinc (Zn) concentration.

The most notable result from Table 4-1 is the extremely high level of zinc. The concentration of zinc in the Honduras sample is 28 ppm. According to the World Health Organization, the highest recorded concentration for zinc in drinking water is around 24 ppm. Compared with standards set by the US Environmental Protection Agency for secondary drinking water standards, the threshold is 5 ppm. Any concentration above 5 ppm is thus considered an abnormal amount. Likely causes of high zinc concentrations in drinking water include leaching from pipes and fittings. Galvanized steel pipes and fittings contain zinc and could potentially be a source of zinc contamination. It is possible that the site in Honduras uses galvanized steel pipes in their plumbing, but it is not known.

The existing concentration for zinc of 28 ppm is questionable. Upon further investigation, the high zinc concentration was reproducibly the same value given by the ICP instrument for several different runs. Therefore, it can be confirmed that the zinc concentration shown in the table is valid and actually present in the sample. WHO and USEPA report that high concentrations of zinc significantly affect the taste and appearance of water so it is likely that consumers are aware there is a problem. No such complaints with the Honduras site's drinking water taste or appearance are known. Additionally, since it is not known how the sample was collected or preserved it is necessary to obtain further samples from this source to adequately assess the situation.